REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
February 1-8, 1997

3. REPORT TYPE AND DATES COVERED
Technical

4. TITLE AND SUBTITLE
Automated Data Acquisition and Analysis at the Benefield Anechoic Facility

5. FUNDING NUMBERS

6. AUTHOR(S)
Robert M. Taylor
Jay Pasimio

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Computer Sciences Corporation
P.O. Box 446
Edwards AFB, CA 93524

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
412th Test Wing/EWWA
Building 1030, Benefield Anechoic Facility
Edwards AFB, CA 93524

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Automated data acquisition and analysis methods at the Benefield Anechoic Facility have improved the test process. Programming has primarily been implemented with a graphical programming language for test and evaluation created by Hewlett-Packard call Visual Engineering Environment. First is a Signal Verification System. A second example is an aircraft antenna pattern testing data analysis program called Antenna Pattern Correction Software. A final example is a transmission line network analysis program for remote test equipment.

14. SUBJECT TERMS
Visual Engineering Environment
Benefield Anechoic Facility

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to *stay within the lines to meet optical scanning requirements.*

Block 1. Agency Use Only *(Leave blank)*.

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

C	Contract	PR	Project
G	Grant	TA	Task
PE	Program Element	WU	Work Unit Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. *(If known)*

Block 11. Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

- **DOD** - See DoDD 5230.24, "Distribution Statements on Technical Documents."
- **DOE** - See authorities.
- **NASA** - See Handbook NHB 2200.2.
- **NTIS** - Leave blank.

Block 12b. Distribution Code.

- **DOD** - Leave blank.
- **DOE** - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.
- **NASA** - Leave blank.
- **NTIS** - Leave blank.

Block 13. Abstract. Include a brief *(Maximum 200 words)* factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

Automated Data Acquisition and Analysis at the Benefield Anechoic Facility

Robert M. Taylor
Computer Sciences Corporation
P.O. Box 446, Bldg. 1030
Edwards AFB, CA 93524
805-277-5717
taylorr%eww@mhs.elan.af.mil

Jay Pasimio
Computer Sciences Corporation
P.O. Box 446
Edwards AFB, CA 93523
805-277-5741
pasimio%eww@mhs.elan.af.mil

Abstract—Automated data acquisition and analysis methods at the Benefield Anechoic Facility have improved the test process. Programming has primarily been implemented with a graphical programming language for test and evaluation created by Hewlett-Packard called Visual Engineering Environment (HP-VEE®). First is a Signal Verification System (SVS) (Reference 1). A second example is an aircraft antenna pattern testing data analysis program called Antenna Pattern Correction Software (APCS). A final example is a transmission line network analysis program for remote test equipment.

TABLE OF CONTENTS

1. INTRODUCTION
2. SIGNAL VERIFICATION SYSTEM
3. ANTENNA PATTERNS
4. TRANSMISSION LINE NETWORKS
5. SUMMARY
6. CONCLUSIONS AND RECOMMENDATIONS
7. REFERENCES

1. INTRODUCTION

The Benefield Anechoic Facility (BAF) is part of the Avionics Test and Integration Complex at Edwards Air Force Base, California. The BAF is primarily an aircraft avionics and electronic warfare test and evaluation facility. However, the size of the BAF makes it a viable test resource for a wide variety of platforms. Dimensions of anechoic chamber are 250-foot width, 264-foot length, and 70-foot height. The chamber is equipped with a ceiling hoist capable of lifting 40 tons and a 80-foot diameter floor turntable capable of turning 250,000 pounds from 0.1 to 0.6 degree per second. Aircraft utilities provided include electrical, hydraulics, and cooling.

An extensive assortment of simulated emitters can be remotely programmed using a Combat Electromagnetic Environment Simulator (CEESIM) and transmitted to the aircraft located in the anechoic chamber. Radar absorbing material (RAM) covers the walls, floor and ceiling to minimize reflections and to simulate a free-space environment. Typically, aircraft are tested in the BAF anechoic chamber for various parameters of electronic warfare through radiated emissions.

Automated data acquisition and analysis methods have greatly increased the efficiency of the test process at the BAF. Programming has principally been implemented with a software package created by Hewlett-Packard called Visual Engineering Environment (HP-VEE®). The HP-VEE® is a graphical programming environment essentially used for test equipment control and data reduction, and can reduce program development time by as

much as 80 percent. Several examples show the usefulness HP-VEE® in data acquisition, data analysis, and network analysis.

2. Signal Verification System

The first example of the data acquisition and analysis automation improvements is a Signal Verification System (SVS). Previously, signals were verified through manual operation of test equipment. Measurements were time consuming and tedious for operators. The SVS was developed to assist operators and to permit measurements to be computer controlled by capturing the signal of interest, characterizing the parameters as required, and then reducing the data to a user-friendly format for identification.

The BAF houses a CEESIM (8K model) in a shielded room attached to the anechoic chamber. The CEESIM is an advanced multichannel simulator capable of generating battlefield scenarios with many emitters up to millions of pulses per second. Emitters are time division multiplexed for simultaneous transmissions, and are amplitude modulated to simulate antenna scans. The RF pulses are digitally generated and transferred to an RF system of channels to individual antennas located inside of the chamber. The signals are then radiated to aircraft in the chamber. The installed avionics and electronic warfare systems of the developmental or operational aircraft are then tested and analyzed for their response to the emitted signals. The anechoic chamber will support fighter, cargo, and bomber-sized aircraft.

Prior to anechoic chamber testing, programmed signals are checked to verify that the RF signals are close approximations of actual systems. Parameters that may require verification include pulse width, pulse repetition frequency, chirp bandwidth, various modulations, scan rates, and simulated antenna patterns. Measurement equipment included a spectrum analyzer, modulation domain analyzer, and an oscilloscope. Prior to the development of the SVS, each signal had to be manually captured and analyzed for individual characteristics on each piece of test equipment. Human operator errors occurred because of the volume of data and the continuous repetition of tasks.

The SVS was developed using HP-VEE® and a computer workstation with drivers for the various signal analysis test equipment. The SVS program was written so that the operation of signal verification was automated to a user-friendly level for many simple and complex signals. Figure 1 shows a block diagram of the SVS system. Figure 2 shows an example of an analysis by the SVS of an RF signal generated by the CEESIM. The SVS analysis showed that the example signal had a dwelling pulse repetition interval (PRI) modulation, where the PRI was the same for several pulses.

The SVS was implemented into the BAF threat generation system for a travelling wave tube amplifier configuration. Metrics were taken before and after the SVS was installed and showed a significant reduction in operator time of over 50 percent.

3. Antenna Patterns

A second example is aircraft antenna pattern testing data analysis automation. Antenna patterns of installed systems in the BAF are useful in determining blockage from the aircraft features in the antenna pattern, the gain of the antenna on the aircraft, polarization, and pattern coverage.

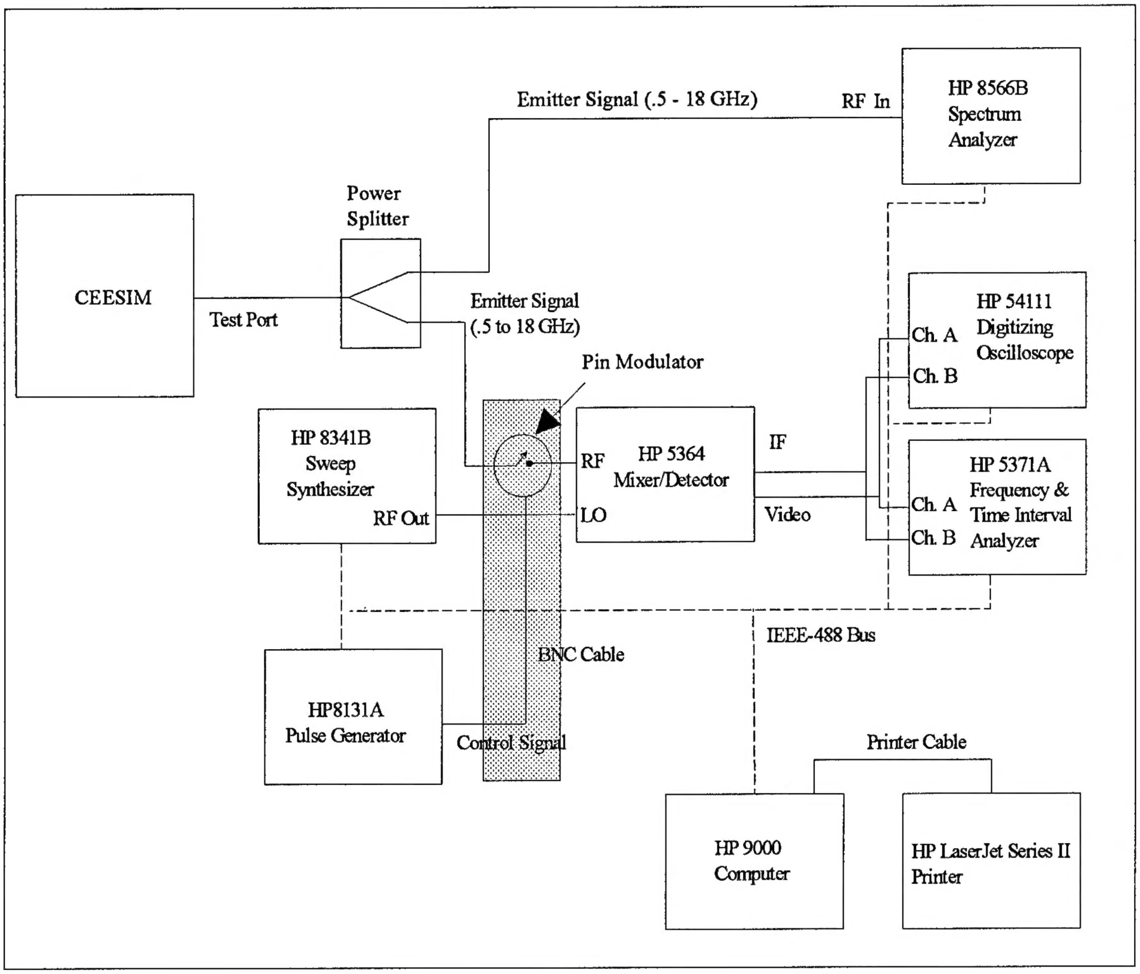


Figure 1. SVS Block Diagram

Far-field conditions may be obtained in the BAF for large apertures and ground planes due to the size (250-foot width, 264-foot length, and 70-foot height) of the anechoic chamber. Far-field patterns can also be obtained for aircraft antenna apertures when only the aperture size is considered, though scattering from aircraft features will introduce near-field errors due to the size of the aircraft.

When taking antenna patterns on aircraft apertures, the aircraft is typically rotated in azimuth from the center of gravity, and the antennas are not coincident from the center of rotation. In some cases the antenna radius of rotation may be several feet. Antenna pattern rotations are referenced to the antenna, so an algorithm was developed to translate from an aircraft orientation to the location of the antennas.

The offset center-of-rotation creates errors in the antenna pattern from parallax and free-space attenuation. Figure 3 shows the geometry of the angular error introduced from the center-of-rotation offset.

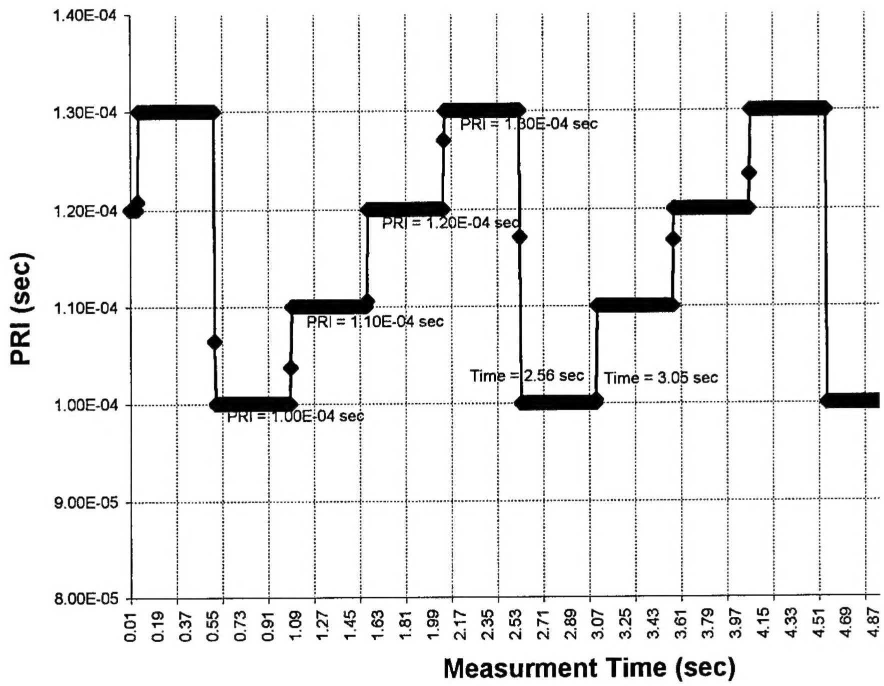


Figure 2. Plot of Dwelling PRI Modulated Signal. Total acquisition time was about 6 seconds covering two dwelling cycles. The following PRI values were measured: 100 usec, 110 usec, 120 usec, 130 usec.

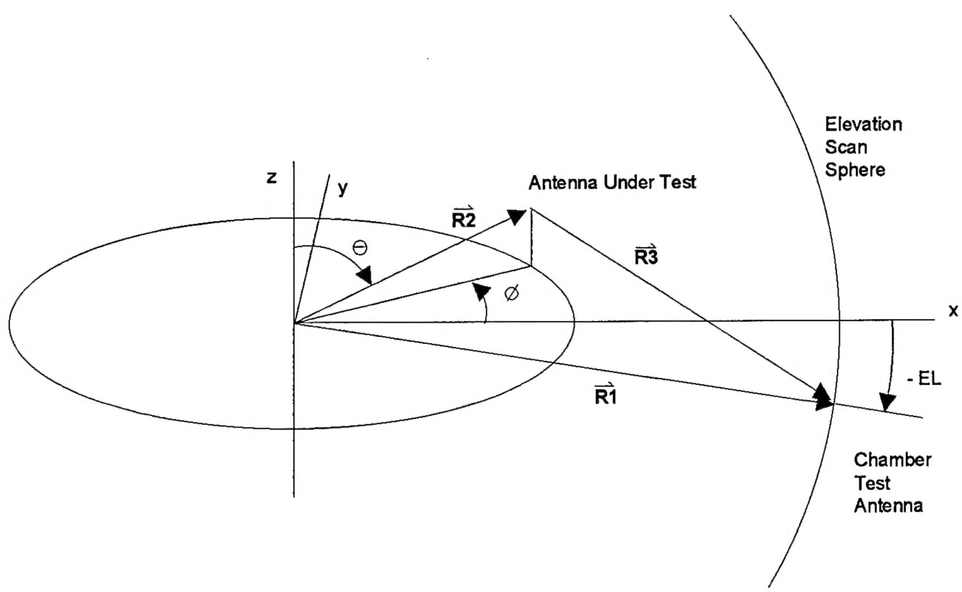


Figure 3. Antenna Pattern Center-of-Rotation Offset Configuration

A software program called Antenna Pattern Correction Software (APCS) was developed on HP-VEE®. The APCS corrects for the center-of-rotation offset errors and computes the antenna gain through a measured antenna pattern integration. Figure 4 shows an overview of the HP-VEE® APCS software, and Figure 5 shows an expanded view of the Phi Correction and Interpolation layer from Figure 4.

Figure 6 shows a measure antenna pattern before and after the APCS was applied. Comparisons show good agreement after the APCS correction is applied between patterns measured in the BAF with patterns measured at an outdoor facility shows.

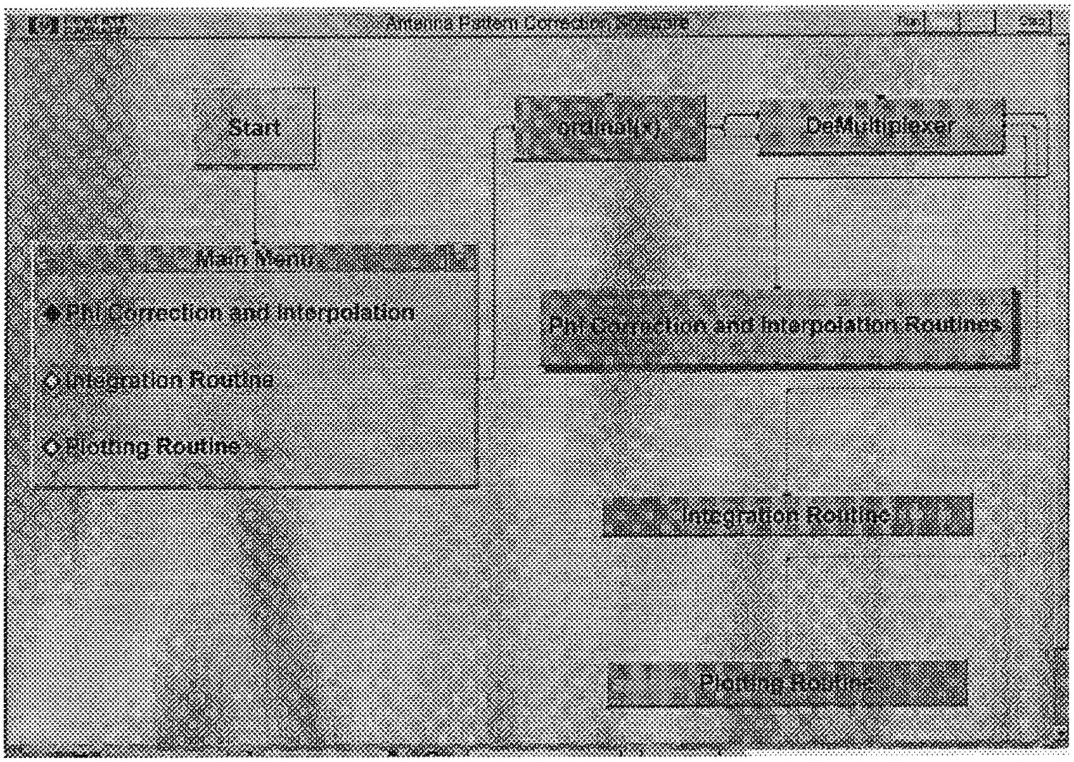


Figure 4. HP-VEE® APCS Summary Layer

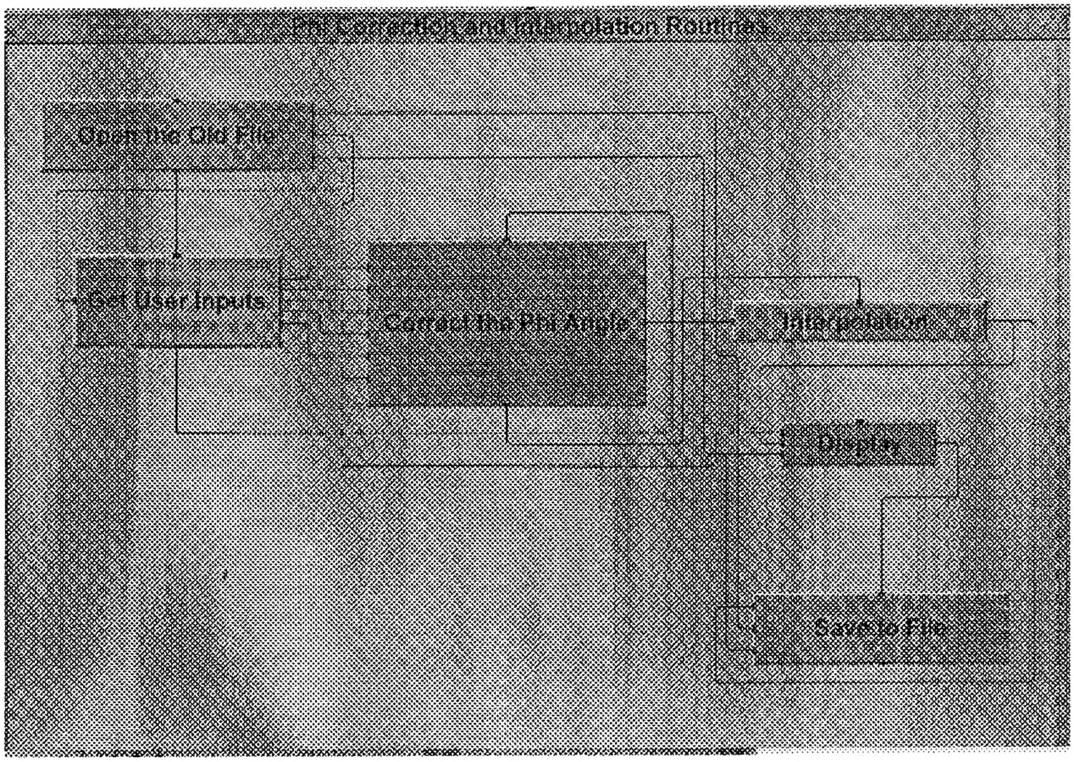


Figure 5. Phi Correction and Interpolation Layer of HP-VEE® APCS

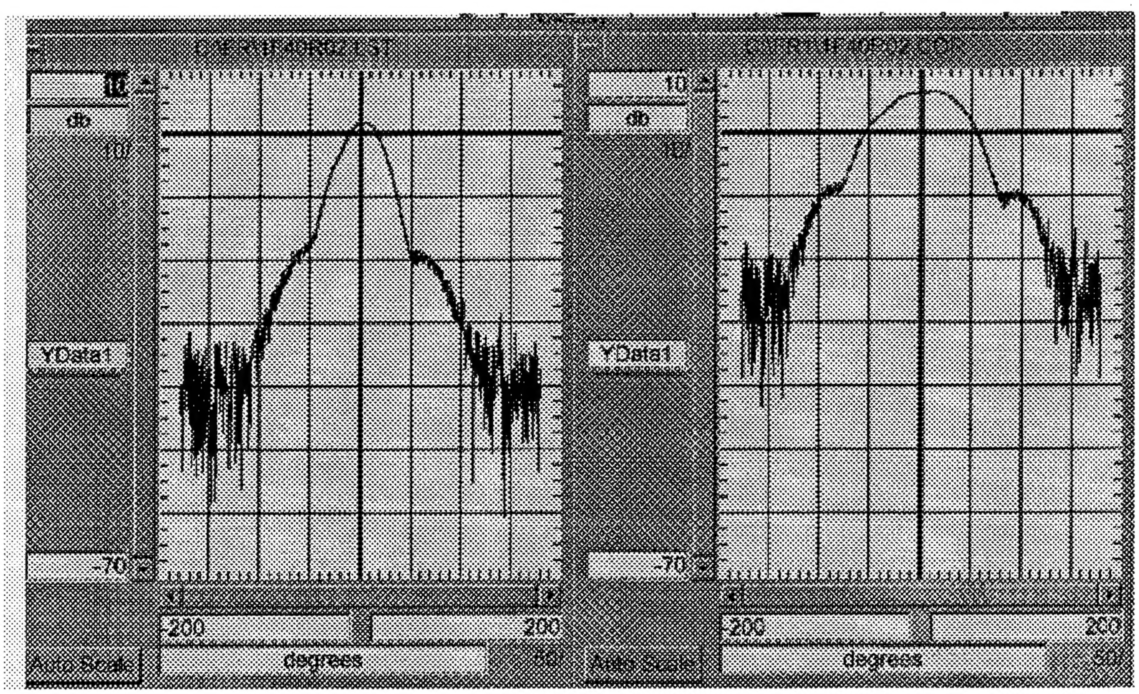


Figure 6. Antenna Pattern Before and After HP-VEE APCS Algorithm Applied

A pattern integration directivity algorithm was also included in APCS. Comparisons were within 0.3 dB of measured gains on an outdoor range without the aircraft with those measured in the BAF with the aircraft over several elevation angles and with the APCS algorithm applied.

4. Transmission Line Networks

A final example of data analysis improvements provided by the HP-VEE® at the BAF was in transmission line network analysis for remote test equipment. Test equipment is typically removed from jacked or hoisted aircraft to minimize interference with measurements. Power levels measured at test equipment frequently must be translated to another location. Measured data were acquired from transmission line parameters of cables and distributed components. Previously, only the transmission loss (or S21 scattering parameters) of each component was added in series, which was less accurate as the input and output impedance matching degrades for components. An algorithm was needed to combine the full S-parameter set for system calibration for all load impedance cases, especially when only component measurements were possible.

A new algorithm includes all four scattering parameters of each component as shown in Figure 7, and uses the transducer gain equation for the combined circuit as in Equation 1. Although the system could include components cascaded throughout the network, only the contiguous component was included in each network. The measured data is combined into a system, and then reduced to an equivalent network as in Figures 8 and 9. Network algorithms are then used to translate power information through the equivalent network to remote locations. More accurate results may be obtained with the new algorithm.

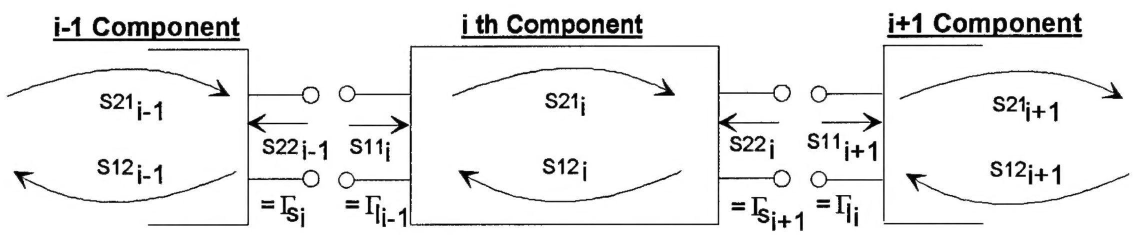


Figure 7. Single Component S-Parameter Network

$$G_T = \frac{|S21|^2 (1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|(1-S11\Gamma_S)(1-S22\Gamma_L)-S21S12\Gamma_S\Gamma_L|^2} \quad (1)$$

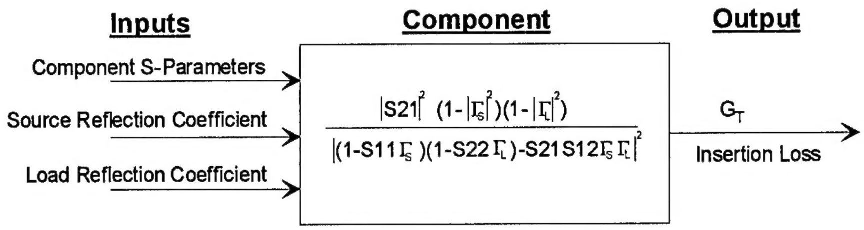


Figure 8. Single Component System Diagram

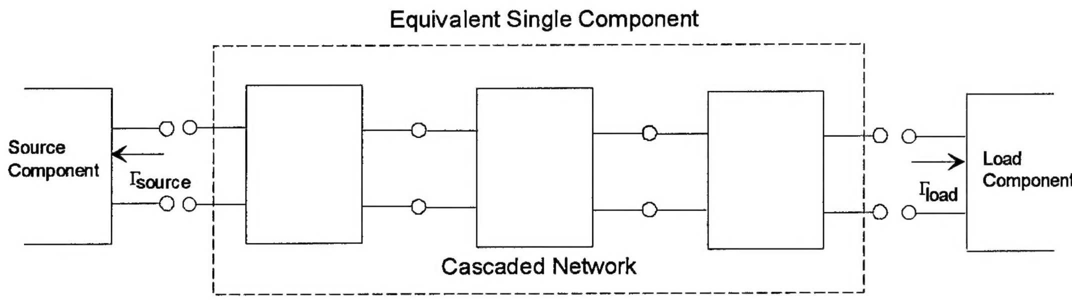


Figure 9. Equivalent Single Component for a Three Component Series Cascaded Network

A test was conducted to check the new algorithm when compared to system measurements. A simple, three component setup was measured including a band-pass filter and a coaxial cable on each side. Each component was measured separately and then the system was measured. The S-Parameters were combined using the new transducer gain algorithm and the previous method of cascaded S21 parameters. Since the cables and filter are all impedance matched within the band measured, all of the data is expected to be very comparable. Table 1 shows a comparison of the three methods, and as expected, the results are very comparable.

Table 1. Cascaded S-Parameter Comparison of Band-Pass Filter Between Two Transmission Lines

Frequency (GHz)	Transducer Equation Combination (dB)	Cascaded S21 Parameters (dB)	System Measurement (dB)
1.4	-2.137	-2.044	-2.080
1.75	-0.177	-0.167	-0.1713
2.0	-0.722	-0.707	-0.726
2.25	-0.912	-0.841	-0.869
2.5	-1.209	-1.192	-1.273

5. Summary

Several data acquisition and analysis programs have been developed at the BAF to aid in test and evaluation. The SVS was developed to verify threat emitter parameters at the RF level. The APCS was developed to translate aircraft antenna pattern rotation from the center-of-gravity to the antenna location, and to compute a pattern integration. Remote transmission line measurements are programmed using HP-VEE® frequently, though the algorithm used is less accurate for unmatched loads. A transmission line network program was developed to improve the accuracy of the programs for all cases.

6. Conclusions and Recommendations

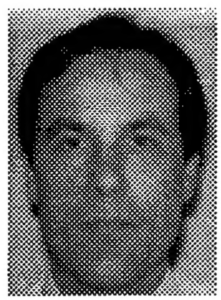
Programming with the HP-VEE® has been very successful in improving test and evaluation at the BAF. The program reduces operator time and improves the accuracy of measurements. The SVS was successful in automating data acquisition and analysis of the threat generation system in a travelling wave tube amplifier configuration, which was shown to reduce measurement time significantly. Measurements of lower power levels will be investigated in the future such as for solid state amplifiers. The APCS applied to installed antenna measured data compared successfully to antenna patterns and gains measured on an outdoor range with a stand-alone antenna. A transmission line network algorithm was verified successfully and continued development of the algorithm and implementation will improve the accuracy of calibrations and remote measurement data. Future measurements will include more comprehensive networks with variable loads impedance. Programming using HP-VEE® will continue to improve the test and evaluation process at the BAF and is recommended for all measurements with automation needs.

7. References

[1] *HP VEE Reference*, Hewlett Packard Co., Edition 4, January, 1995.

[2] Constantine Balanis, *Antenna Theory, Analysis and Design*, Harpers and Row, Publishers, Inc., New York, 1982.

[3] Guillermo Gonzalez, *Microwave Transistor Amplifiers*, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1984.



***Robert M. Taylor** holds a Bachelor of Science degree in Engineering Science and Mechanics from the University of Florida, Gainesville, a Masters of Science degree in Electrical Engineering from California State University at Northridge, and a Masters of Science degree in Systems Management from the University of Southern California. Robert has been a Principal Engineer of test and evaluation project planning of aircraft installed avionics and electronic warfare systems for Computer Sciences Corporation (CSC) at the Benefield Anechoic Facility, Edwards Air Force Base, California, since 1990. Prior to CSC, he developed antennas, microwave circuits, low observable structures and materials at Lockheed Aeronautical Systems Corporation in Burbank, California (1985-1990) and Cubic Defense Systems Corporation, San Diego, California (1982-1985). He has extensive experience in antenna and radar cross section measurements, electromagnetic*

modeling, and electronic warfare simulation systems.

Jay Pasimio *holds a Bachelor of Science degree Computer Science from the University of La Verne. He has developed several data acquisition and data processing systems for Computer Sciences Corporation (CSC) at the Benefield Anechoic Facility, Edwards Air Force Base, California since 1992. Prior to CSC, he wrote software for a secure communications system at Rockwell International in San Bernardino, California. He also developed software for test automation and missile guidance at General Dynamics in Pomona, California (1979-1990).*